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# Quality Characteristics of Midwestern Soybeans

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## ABSTRACT

**S**OYBEANS, from the 1983 and 1984 crops, were analyzed for official grade-factors, protein/oil composition, and breakage susceptibility. Samples were collected from 13 locations across four states. U.S. Grades did not differ greatly between years or sample origins, but nutrients and breakage susceptibility did. The average protein and oil percentages, basis 13.0% moisture, were 33.9, 19.7 and 34.2, 19.1 for 1983 and 1984 respectively. Several equations were developed to interrelate quality factors. For a one-percentage-point increase in protein content, there was an average decline of 0.43 percentage points of oil. This relationship varied by origin, with some origins showing less loss in oil for increase in protein. Breakage susceptibility, by the

Wisconsin breakage tester, increased 22% for a one-percentage-point fall in moisture content.

## INTRODUCTION

In 1985, the United States produced about 2 billion bushels of soybeans, 310 million bushels in Iowa alone (Iowa Crop and Livestock Reporting Service, 1985a). Of these, 95% were crushed into soybean meal and soybean oil, either in the U.S. or overseas (Iowa Crop and Livestock Reporting Service, 1985b). Soybean quality, for trading purposes, is described by the Official Grades for soybeans, shown in Table 1.

Recently, some U.S. export customers have stated that U.S. soybeans are of lesser quality (higher damage and foreign material, lower protein and oil) than soybeans from other origins (Feedstuffs, 1985a,b). Worldwide quality differences have been documented through United States Department of Agriculture (USDA) studies (Nicholas, 1978; Nicholas and Whitten, 1978) and recent trade missions. The quality factors of most concern to users are foreign material, moisture content, and nutrient (protein and oil) composition. Foreign material and moisture content are certified officially, but nutrient testing is not routine in either national or international trade.

Protein and oil contents determine soybean meal and oil yields; therefore, one would expect them to be useful as marketing factors. Discussions with processors reveal that nutrient purchasing is occurring informally in that each had opinions as to where the highest-value beans could be bought. However, no direct nutrient incentives are available to producers. Breakage susceptibility is related to meal and oil value; breakage-prone soybeans

Article was submitted for publication in August, 1986; reviewed and approved for publication by the Food and Process Engineering Institute in May, 1987. Presented as ASAE Paper No. 85-3554.

Research supported by the Iowa Soybean Promotion Board and the Iowa Agriculture and Home Economics Experiment Station.

Journal Paper J-12342 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Ames. Project 2339.

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**Acknowledgments:** The authors are grateful for the sample-collection assistance of Mr. Russell Doorenbos, Iowa Soybean Association, Mr. Alex Cerne, Minnesota Soybean Association, Mr. Wally Furrow, El Paso Grain Co., and Dr. Glenn Hall, the Andersons, Inc. Greg Gibson, Jon Lyon, Liisa Schmitt, Dave Metzger, and Scott Schnicker all spent many hours testing grain in our lab. Our thanks also goes to Claudia Buttery for careful reparation of manuscripts.

TABLE 1. OFFICIAL U.S. GRADES FOR SOYBEANS (FGIS 1984a)

Grade	Minimum test weight per bushel, lb	Moisture <sup>‡</sup> , %	Splits, %	Maximum limits of --			
				Damaged kernels			Brown, black and/or bicolored soybeans in yellow or green soybeans, %
				Total, %	Heat damaged, %	Foreign material, %	
U.S. No. 1	56.0	13.0	10.0	2.0	0.2	1.0	1.0
U.S. No. 2	54.0	14.0	20.0	3.0	0.5	2.0	2.0
U.S. No. 3*	52.0	16.0	30.0	5.0	1.0	3.0	5.0
U.S. No. 4†	49.0	18.0	40.0	8.0	3.0	5.0	10.0
U.S. Sample grade	U.S. Sample grade shall be soybeans which do not meet the requirements for any of the grades from U.S. No. 1 to U.S. No. 4, inclusive; or which are musty, sour, or heating; or which have any commercially objectionable foreign odor; or which contain stones; or which are otherwise of distinctly low quality.						

\*Soybeans which are purple mottled or stained shall be graded not higher than U.S. No. 3.

†Soybeans which are materially weathered shall be graded not higher than U.S. No. 4.

‡Moisture was removed from the grade standards on September 1, 1985.

split easily, reducing oil quality (Nicholas, 1978).

The development of near-infrared technology and its successful application to soybean testing (Hymowitz et al., 1974; Iverson, 1983) make local-market nutrient measurements possible. To assess the potential value of these and other descriptive quality tests, an estimate is needed of quality variations in soybeans as delivered to country markets. This study was initiated to collect background information for a soybean quality-improvement strategy.

## OBJECTIVES

With support from the Iowa Soybean Promotion Board, several aspects of soybean quality were studied in the harvest seasons of 1983 and 1984. The following objectives are addressed in this article:

1. Determine the variations in quality, as measured by U.S. Grade factors, protein/oil content and breakage susceptibility, of soybeans delivered to midwest country elevators, with emphasis on Iowa.
2. Classify quality differences as arising from regional effects, year-to-year effects and lot-to-lot effects, within a region.
3. Quantify correlations among soybean quality characteristics.

## MATERIALS AND METHODS

### Sample Collection

Soybean samples were collected at nine country elevators across Iowa, about 30 samples per elevator per year. Sample groups were also obtained from Minnesota (several elevators pooled), one elevator in central Illinois (1983 only), and one elevator in northwestern Ohio. The map in Fig. 1 shows the location of the elevators. Samples from locations 6, 7, 11, 12, and 13 were collected by cooperators; at all other locations, University personnel collected the samples. For all locations except location 11 (Illinois), samples were collected with a pelican (FGIS, 1983), mechanical diverter or pan (Hurburgh et al., 1979). These methods

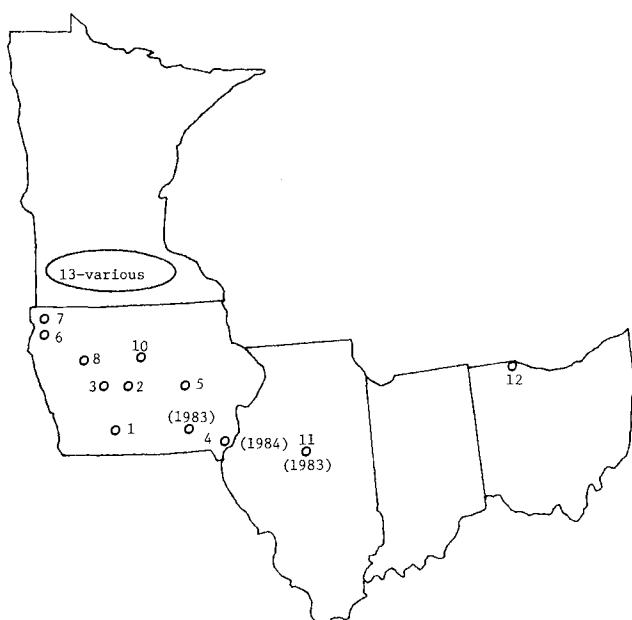


Fig. 1—Identification and location of elevators where soybean samples were collected.

yielded representative samples large enough to complete all necessary laboratory analysis. The Illinois samples were mechanical-probe samples used by the elevator to settle with producers. They had been cleaned in the initial grading process, so official grade-factor determinations could not be made.

### Laboratory Procedures

All laboratory testing was done in the Iowa State University Grain Quality Laboratory, with the following exception. Samples larger than 3000 g were divided in a Boerner divider, with one split, 1500 g or more, sent to Eastern Iowa Grain Inspection Service (EIGI), an FGIS designated agency, for grading by official methods (FGIS, 1980a). EIGI measured foreign material, splits, test weight, and damage. If samples were not large enough to provide 1500 g for EIGI, then official factor tests were done at Iowa State. A 36-sample comparative study showed no statistically significant differences between Iowa State and EIGI.

The portion of a sample retained by Iowa State was then cleaned with the 4.0 mm  $\times$  19.2 mm (10/64-in.  $\times$  3/4-in.) slot sieve used for splits determination. All through-material and any bulky nongrain material atop the sieve were discarded. Pods containing beans were shelled, and the beans returned to the sample.

A 40-g first-stage subsample was removed to begin the USDA two-stage oven moisture test (FGIS, 1984b). After 48 h of equilibrium to room conditions, the first-stage subsample was ground through an 18-mesh screen in a Wiley intermediate mill. The ground material was divided into triplicate 8 to 10 g samples and dried at 130°C for 1 h.

Between 200 and 250 g were weighed to the nearest 0.1 g and passed through the Wisconsin breakage tester. Breakage susceptibility was determined by screening the broken beans on the splits sieve for 20 cycles in a Gamet shaker. The overs were weighed, with breakage susceptibility calculated as 100 minus the percentage of overs.

To measure protein and oil content, about 100 g were ground to a fine flour in a Magic Mill III+ home flour mill. The flour was mixed and subsampled three times for near-infrared reflectance (NIR) analysis with a Dickey-john GACIII instrument. The GACIII was calibrated at Iowa State to measure protein by the Kjeldahl method,

TABLE 2. SOYBEAN CALIBRATIONS\* FOR THE DICKEY-JOHN GACIII NEAR-INFRARED REFLECTANCE ANALYZER

Statistic	Moisture†	Constituent protein‡	Oil§
Wavelengths, nm	2310, 2180, 1940	2310, 2180, 2100, 1680	2310, 2180, 1940, 1680
Calibration samples			
Number	101	134	133
Average, % (as-is moisture)	9.50	35.48	20.14
Maximum, %	15.69	39.91	22.00
Minimum, %	6.73	32.00	17.32
Calibration regression			
R-square, %	97.9	84.9	72.4
Standard deviation, points	0.22	0.69	0.69
Coefficient of variation, %	2.3	1.9	3.4

\*Magic Mill III+ home flour mill.

†Ground-grain, 130 °C, 1 h air-oven, 8-10 g samples.

‡Kjeldahl, 40 min digestion, CuSO<sub>4</sub> catalyst.

§Goldfish, 5 h extraction with petroleum ether, 40-50 °C boiling point.

||Square root of regression mean square error.

oil by the Goldfisch method and moisture (of the ground material) by the USDA method. Table 2 contains a summary of the pertinent statistics relative to the NIR calibrations. For comparison, Hurburgh et al. (1985) reported that electronic moisture meters have a coefficient of variation relative to oven moisture of 3 to 4%. Soybeans from 1983 and 1984 were used for the GACIII calibrations. Percentages were converted from the "as is" moisture basis to the 13% moisture basis before statistical analysis.

The remainder of the sample was conditioned to 13.0% moisture, by room air-drying if whole-grain moisture was greater than 13% or by humid air

remoisturization if whole-grain moisture was less than 13%. Humidification was done in a Lab-line environment chamber maintained at 20°C, 80% relative humidity. Conditioning took between 2 h and a week, with the shorter times for very small (less than 0.2%) changes. Attainment of a calculated increase or decrease in sample weight was the criterion for completion of conditioning. The conditioned samples were retested through the Wisconsin breakage tester.

### Statistical Analysis

The data for each quality factor were grouped by elevator of origin and crop year. An analysis of variance

TABLE 3. SUMMARY OF OFFICIAL GRADE-FACTOR DATA FOR THE SOYBEAN QUALITY SURVEY, BY YEAR AND ORIGIN

Elevator (crop district)	Year	n	Average value of:				Distribution of samples by U.S. Grade, 1-2-3-4-Sample
			Test wt., lb/bu	Foreign material, %	Splits, %	Damage, %	
7 (SW)	1983	30	55.3	1.6	5.5	0.1	8-13-5-1-3
	1984	30	55.9	0.8	6.9	0.0	14-13-3-0-0
6 (NW)	1983	28	54.7	0.8	6.4	0.1	3-16-8-0-1
	1984	32	55.1	1.7	8.7	0.0	5-14-6-6-2
3 (WC)	1983	26	56.3	0.7	1.2	0.0	19-7-1-0-0
	1984	29	56.1	0.8	3.0	0.0	21-7-1-0-0
8 (WC)	1983	30	56.6	0.5	1.5	0.0	27-3-0-0-0
	1984	10	56.2	0.9	4.2	0.0	3-7-0-0-0
1 (SC)	1983	25	55.9	1.0	3.8	0.0	9-13-1-0-1
	1984	24	55.7	2.1	10.2	0.4	4-10-6-2-2
2(C)	1983	30	56.3	0.6	2.1	0.0	22-7-1-0-0
	1984	30	56.6	0.9	0.9	0.4	17-10-1-0-1
10 (C)	1983	40	57.3	0.7	1.7	0.4	34-5-1-0-0
	1984	26	56.3	0.8	2.7	0.0	16-8-2-0-0
5 (EC)	1983	22	55.7	0.9	2.7	0.0	7-14-1-0-0
	1984	30	56.2	0.9	4.4	0.9	19-10-1-0-0
4 (SE)	1983	15	56.6	1.1	2.1	0.6	6-7-1-1-0
	1984	29	56.5	0.7	4.3	0.1	22-4-3-0-0
12 (OH-NW)	1984	30	56.7	0.7	2.4	0.0	16-13-1-0-0
	1983	32	56.3	0.6	2.1	0.0	15-16-1-0-0
Averages, sample groups with official grades both years							
	1983	276	56.18	0.83	2.93	0.1	151-98-20-2-5
Export quality, 1983-1984 marketings (FGIS 1985)							
		654	55.8	1.9	7.1	0.9	9-575-64-6-0
13 (MN-various)	1983	31	55.4	0.9	5.9	0.2	6-22-3-0-0
	1984	44	55.1	—	—	—	—
11 (IL-C)	1983	20	55.7	—	—	—	—
Comparison statistics							
LSD <sub>0.05</sub>							
between years			0.15	0.15	0.51	*	
among elevators			0.34	0.32	1.12	*	
among sample groups			0.49	0.46	1.62	*	
Standard deviation within a group							
			0.9	0.9	3.1	*	

\*Not applicable because 80% of samples tested 0.0% damage.

determined year and elevator means, with the Fischer least-significant difference (LSD) test (SAS, 1985) used to establish significantly different means.

Simple correlation coefficients ( $r_{x_1, x_2}$ ) were obtained for all factors relative to one another. The coefficient for a factor-pair was judged useful if the absolute value was greater than 0.29 for both years and the factor pair represented a conceptually informative relationship.

Regression equations were established for factor pairs that had correlations absolute values greater than 0.5 in both years. The effect of moisture on breakage susceptibility was also determined from the breakage susceptibility change between the "as received" and conditioned tests. Only regressions significant beyond the 0.01 probability level are presented.

## RESULTS AND DISCUSSION

### U.S. Grade Factors

Table 3 is a summary of U.S. Grade-factor results by elevator origin and a distribution of U.S. Grade assignments within each sample group. On the basis of factor averages, the soybeans averaged No. 1 yellow in both years, but in individual samples, about half graded No. 2 yellow or worse. All factors were grade-determining for at least one sample. Only rarely did a sample have more than one grade-determining factor. Test weight was grade-determining the most often (172 times), followed by foreign material (149 times), splits (20 times), and damage (4 times). In country elevator practice, moisture is the most frequently measured

TABLE 4. SUMMARY OF NUTRIENT AND BREAKAGE SUSCEPTIBILITY DATA FOR THE SOYBEAN QUALITY SURVEY, BY YEAR AND ORIGIN

Elevator (crop district)	Year	n	Oven moisture content, %	Nutrient content, % basis 13.0% moisture				Breakage susceptibility, %	
				Protein +	Oil	=	Sum	As received moisture	At 13.0% moisture
7 (NW)	1983	30	12.00	32.5	20.2		52.7	23.2	16.1
	1984	30	10.41	33.2	19.3		52.5	31.0	20.2
6 (NW)	1983	28	11.95	33.3	19.7		53.0	35.2	27.1
	2984	32	9.92	33.5	19.1		52.6	43.4	30.0
3 (WC)	1983	30	11.99	34.2	19.7		53.9	13.5	11.4
	1984	30	12.03	33.6	19.3		52.9	19.2	15.8
8 (WC)	1983	30	11.98	34.1	19.6		53.7	16.3	12.4
	1984	10	11.34	33.1	19.3		52.4	24.8	16.3
1 (SW)	1983	25	11.17	33.3	19.8		53.1	17.3	13.7
	1984	24	12.79	33.3	19.5		52.8	25.3	25.1
2 (C)	1983	26	11.85	34.3	19.3		53.6	11.9	9.7
	1984	29	11.17	34.4	19.3		53.7	12.8	6.6
10 (NC)	1983	40	10.92	34.3	19.6		53.9	15.6	12.8
	1984	26	11.43	34.6	19.1		53.7	15.6	11.3
5 (EC)	1983	22	12.30	33.7	19.9		53.6	15.1	13.9
	1984	30	11.68	34.1	19.1		53.2	22.1	19.9
4 (SE)	1983	15	12.06	33.7	20.3		54.0	9.0	7.4
	1984	29	11.66	34.1	19.1		53.2	20.5	19.0
12 (OH-NW)	1983	30	12.68	36.0	18.7		54.7	11.0	10.5
	1984	32	13.25	36.6	17.9		54.5	10.7	12.1
13 (MN - various)	1983	31	12.26	33.5	19.7		53.2	24.3	19.5
	1984	44	11.23	34.4	18.6		53.0	28.9	25.5
Average, groups with boty years data.	1983	307	11.90	33.91	19.70		53.55	18.02	14.54
	1984	316	11.51	34.18	19.10		53.28	23.47	18.83
11 (IL-C)	1983	20	12.28	33.7	20.1		53.8	26.3	24.3
Comparison statistics									
LSD <sub>0.05</sub> :									
between years			0.24	0.16	0.08		0.10	1.55	1.23
among elevators			0.46	0.37	0.18		0.24	3.60	2.87
among sample groups			0.67	0.54	0.27		0.35	5.19	4.14
Standard deviation within a group			1.27	1.0	0.5		0.7	9.9	7.9

factor, followed by foreign material. The average foreign material content, 0.93%, left little room for blending or breakage to merchandise No. 1 yellow soybeans with a maximum of 1.0% foreign material. It is not surprising that FGIS' 1984 survey of exports showed No. 2 yellow to be the most often exported grade (FGIS, 1985).

The U.S. grade-quality was slightly lower in 1984 than 1983. This was caused by an early frost and poorer herbicide performance, increasing the amount of foreign material. Some areas experienced damage problems in 1984 because of "green beans" frost damage before maturity. Only 20% of samples had measurable damage, however.

There were no striking locational differences in U.S. Grade results. On U.S. Grade factors alone, there was little distinction among sample groups, even those from Minnesota and Ohio, distant origins relative to Iowa. There was a lower proportion of U.S. No. 1 grades in the samples from south-central and northwestern Iowa, caused by higher foreign material levels.

### Nutrient Content and Breakage Susceptibility

There were clearer regional and year-to-year differences in these quality factors than in U.S. Grade factors. Table 4 gives a listing, again by elevator origin and year, of nutrient and breakage susceptibility data.

There was little pattern in moisture, except that the Ohio soybeans were the wettest, both years. Soybeans from the Great Lakes area had the highest moisture in the FGIS data also. The particular day and time of day probably had more influence on moisture content than did origin or year. Almost invariably the soybeans were below the 13% trading standard. In the FGIS study (FGIS, 1985) the average export moisture was 12.6%

The two nutrient measures, protein and oil, changed regionally and between the years. The 1983 season was generally dry across the Midwest, with extreme drought in southern and western Iowa. Processors believe that hot, dry conditions will produce higher oil percentages; our data support that view. Overall, oil content was higher in 1983, with the highest oil groups coming from elevators in the areas with more severe drought. Dry weather prevailed in southwestern Iowa in 1984; the southwestern Iowa elevator (No. 1) produced the highest oil samples in 1984. An inverse relationship between protein and oil is evident in both years.

According to processor opinions, soybeans from northern origins are lower in oil content. This was not the case, but there was a pattern in the relationship of protein and oil. The pattern can best be illustrated by comparing the sums of protein and oil percentages. Soybeans from the northern and western locations were consistently below their respective yearly average in the sum statistic. Therefore the loss in protein for a given gain in oil content was higher in these locations.

These data raise several questions for marketing and grain elevator management. What criteria, for example, should one use to select the "highest value" soybeans? And given a selection process, how would one protect the choice from shifts in relative soybean meal and soybean oil prices? The value of a particular analysis depends on the relative prices of soybean crush products. Soybeans cannot be ranked best to worst on only nutrient percentages.

The largest differences among sample groups occurred in breakage susceptibility. The most northern and

TABLE 5. USEFUL\* CORRELATIONS AMONG SOYBEAN QUALITY FACTORS

Factor pair	Correlation coefficient	
	1983	1984
Test weight - whole grain moisture	-0.30	-0.30
Test weight - brk. susc. @ 13% mst.	-0.44	-0.32
Test weight - protein as received	0.44	0.36
Brk. susc. as received - splits	0.61	0.57
Protein as received - oil as received	-0.64	-0.52
Protein @ 13% mst. - oil @ 13% mst.	-0.82	-0.89
Sum † - Protein @ 13% mst.	0.90	0.93
Sum - Oil @ 13% mst.	-0.49	-0.66

\*Absolute value  $\geq 0.3$  both years.

†Protein @ 13% moisture plus oil @ 13% moisture

western locations had roughly twice the breakage susceptibility central and eastern locations. In general, the lower the sum of protein and oil, the higher the breakage susceptibility as measured at the standard 13% moisture. Some origins were remarkably consistent in breakage susceptibility for the two years. The largest change between years was for south-central and southeastern Iowa, where the weather differed greatly between the years.

The variability among loads at a location was quite consistent across origins and years. Thus, the average standard deviation within a group is a good estimator of the variations a grain dealer would experience. For the 13% moisture basis values, this standard deviation was 1.0, 0.5, and 8.0 for protein, oil, and breakage susceptibility, respectively.

### Relationships Among Soybean Quality Factors

There were several consistent correlations among the soybean quality factors. Those correlations with absolute values in both years greater than 0.5 and representing physically significant factor pairs are shown in Table 5.

Test weight was associated with moisture (negatively), breakage susceptibility (negatively), and protein (positively). The test weight-moisture correlation is similar to, but much less certain, than the -0.8 reported from corn (Hall and Hill, 1973; Hurburgh et al., 1985). The negative association of test weight and breakage susceptibility means that denser kernels are generally more fracture-resistant. Protein, being denser than oil, contributed positively to density. However, none of the test weight correlations were strong enough to be predictive on their own. In one case, test weight was useful in a multiple regression.

Breakage susceptibility was reasonably well related to percentage of splits. This indicated that, given a breakage susceptibility test, percentage splits from average combine harvesting could be predicted. Conversely, breakage susceptibility might be predicted from a splits measurement. The two regression equations are:

$$S = 0.505 B_o + 6.1 ; R^2 = 37.3 \quad \dots \dots \dots [1]$$

$$s = 1.2$$

and

$$B_o = 1.979S + 12.0 ; R^2 = 37.3\% \quad \dots \dots \dots [2]$$

$$s = 9.5$$

where

S = splits, %  
 $B_o$  = breakage susceptibility as received, %  
s = standard deviation of regression, percentage points

These equations show that harvest breakage is moderately related to breakage susceptibility as measured by the Wisconsin tester.

A multiple regression related breakage susceptibility to the additional factors of test weight (T, in lb/bu) and delivery moisture (M, in %).

$$B_o = -2.498T + 1.512S - 4.630M + 208.4 ; R^2 = 62.4\% \\ s = 7.5 \dots \dots \dots [3]$$

where

T = test weight, lb/bu  
M = delivery moisture content, %

Equation [3] predicts breakage susceptibility "as received" from measurements of test weight, splits, and moisture. A rearrangement of equation [3] would predict percentage splits from combine-harvest, given the other three tests. The latter formulation could be useful to geneticists evaluating combine-harvest characteristics of varieties.

Protein and oil were inversely related. The correlation was much stronger between standard-moisture values than between "as is" values because of the confounding moisture effect. The equation relating protein and oil on 13.0% moisture basis is:

$$O_{13} = -0.4333P_{13} + 34.08 ; R^2 = 64.7\% \dots \dots [4] \\ = 0.43$$

where

$O_{13}$  = oil content, basis 13% moisture, %  
 $P_{13}$  = protein content, basis 13% moisture, %

In essence, there was a tradeoff of 0.43 percentage points of oil for every percentage point increase in protein.

An opportunity in protein and oil marketing lies in the exceptions to the protein-oil relationship. Samples that lost less than 0.43 percentage points of oil for a one point gain in protein were better, for all meal-oil price combinations, than average.

### Breakage Susceptibility-Moisture Correction

Because all samples were tested for breakage susceptibility at two moistures, "as received" and 13%, the effect of moisture changes on breakage susceptibility of a given sample was determined. Paulsen (1983) and Hurburgh (1984b) have reported a moisture-breakage susceptibility relationship in corn of the form:

$$B_f = B_o(K)^{(M_o - M_f)} \text{ or } B_f = B_o e^{k(M_o - M_f)} \dots \dots [5]$$

where

$B_o$  = breakage susceptibility at original moisture, %  
 $B_f$  = breakage susceptibility at final moisture, %  
 $M_o$  = original moisture, % wet basis  
 $M_f$  = final moisture, % wet basis  
K = breakage constant, power form  
k = breakage constant, exponential form

with K equalling 1.34 and 1.40 for the two corn studies,

respectively. In equations [5]:

$$\ln K = k \dots \dots \dots [6]$$

Sample-by-sample solution for K yielded average values of 1.21 and 1.23 for 1983 and 1984, respectively, with a standard deviation of 0.08 in each year. K was the same for either an increase or a decrease in moisture content. The soybean moisture correction equation for the Wisconsin breakage tester is:

$$B_f = B_o (1.22)^{(M_o - M_f)} \text{ or } B_f = B_o e^{-0.20 (M_o - M_f)} \\ 7.7\% < M_o, M_f < 17.1\% \dots \dots \dots [7]$$

This equation can be used to correct breakage susceptibility tests to any standard moisture content. It can be stated verbally as a 22% compounded change in breakage susceptibility per percentage point change in moisture content.

Equation [7] is *not* a relationship between breakage susceptibility and harvest moisture content. It expresses change in breakage susceptibility as a function of change in moisture for a given sample. The correlation analysis showed that, for our set of samples, there was no significant relationship between "as received" moisture content and "as received" breakage susceptibility. Genetics, harvest damage and other factors combined to obscure any such connection. But once soybean breakage susceptibility was established at a moisture content, it could be converted to another moisture content with equation [7]. This is precisely what a grain buyer would have to do in order to interpret breakage susceptibility data after routine aeration and storage procedures.

### CONCLUSIONS

The quality of producer-delivered midwestern (1983 and 1984 crop) soybeans was determined based on sample groups from 9 Iowa elevators, one Illinois elevator, one Ohio elevator, and various origins in Minnesota.

1. In both years, half the soybean samples graded U.S. No. 1. Foreign material and test weight were the two factors most likely to reduce grade. Average foreign material concentrations were very close to the maximum of 1.0% allowed for U.S. No. 1, which meant that any handling that created foreign material would make the export of U.S. No. 1 beans impossible without cleaning.

2. There were no regional or yearly patterns of practical significance in U.S. Grades or individual grade factor tests.

3. There were differences among origins and across years in oil content (basis 13.0% moisture). The higher oil contents were recorded from the driest growing areas in both years. The overall average oil content was 19.7% and 19.1% for 1983 and 1984, respectively.

4. Protein and oil contents were inversely related, but soybeans from the western third of Iowa and from Minnesota showed a greater protein loss for each percentage point gain in oil. The samples from northwestern Ohio showed the smallest loss in protein per percentage point gain in oil. Protein content averages, basis 13.0% moisture, were 33.9% and 34.2% for 1983 and 1984, respectively.

5. The sample groups varied widely in breakage susceptibility, either as received or adjusted to 13.0% moisture. Generally, those origins showing the lowest sum of protein and oil contents had the highest breakage susceptibility. The average Wisconsin breakage susceptibility, at 13.0% moisture, was 14.5% and 18.8% for 1983 and 1984, respectively.

6. The expected standard deviations among inbound loads to an elevator are 1.0 percentage point, 0.5 percentage points, and 8.0 percentage points for protein, oil and breakage susceptibility, respectively.

7. Several pairs of quality characteristics were correlated. Predictive equations were developed to relate splits, (a) test weight and breakage susceptibility, (b) oil and protein, and (c) breakage susceptibility and moisture. Breakage susceptibility after conditioning to 13.0% moisture changed by a factor of 1.22 for every percentage point change in moisture.

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